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ABSTRACT

In order to examine the nature of dimensional processing in children, 20 kindergarten and 20 third grade Chinese-American children were asked to make similarity judgments for unidimensional sets of stimuli differing in color (hue), size, and shape, respectively. Age differences were generally confined to the color set. The judgments of the older children were more internally consistent, and more similar to the other children in their age group than were the younger children. The frequency of good-fitting Scaling Solutions was also higher for the older children. The processing of color in a relational manner thus seems to develop more slowly than relational processing of size or shape. Implications of these results are discussed. Forty white kindergarten children also did all three tasks. Results for these children indicated the same sequence of difficulty, although these children were less consistent and sophisticated than the Chinese children. (Author/ED)

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Dimensionality in the Similarity Judgments of Young Children

Given at SRCD, April, 1975

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Our basic question in this paper is how do children process different perceptual dimensions. Specifically, 1) are sets of stimuli which vary in similarity along an experimenter-defined single dimension treated by children as components of a dimension; 2) is this phenomenon related to age; and 3) is this relational processing ability demonstrated for all dimensions simultaneously, or might its appearance be related to the nature of the stimuli in theoretically meaningful ways?

The concept of a dimension has great significance in mediational and attentional theories of discrimination learning, but these theories generally treat a dimension simply as a class name for a set of stimulus values (such as brightness as a category name for black and white stimuli). Yet there is a more general definition of a dimension which may suggest alternate conceptualizations of processes in children's learning: we will consider dimensions as ordered transitive continua comprised of different stimuli which can be placed relative to each other to represent a set of similarity relationships. For example, not only are red, orange, green, and blue members of the class, color, but they can also be seen as points on a continuum and as having differing degrees of similarity to each other. If children treat dimensions in accord with the second definition, then

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experiments probably should take this processing into consideration .

Our basic technique was to use non-metric scaling procedures to identify the systematic basis of information processing on several dimensions. While the ultimate analytic procedure was the non-metric scaling, there were several preliminary steps in attaining this goal, along with some relevant intermediate questions that could be asked.

The easiest scaling technique available to the experimenter is to have a subject array objects in as many physical dimensions as necessary with distance as the measure of similarity i.e. - similar stimuli are placed closer together and dissimilar ones further apart. The trouble with this method is that we don't trust it because we don't think all relations are evaluated by the subject.

A second solution is to have a subject give a metric estimate of similarity between many pairs of objects. An apple and a pear might get a score of 1.5 on a ten point scale with 1 being very similar while ice cream and lettuce might be rated 6. Such metric estimates scale very nicely but there is a problem. Young children can't do these estimates very easily.

We have employed a much simpler activity i.e. asking a child to decide which 2 of 3 stimuli are most alike. An example is represented in Fig. 1. Many six year old children can do this task but some children respond according to position or some other low level response. The frequency of this low level responding is undoubtedly much higher in younger children.

If the child were to judge 1 & 2 as most alike and 1 & 6 as least alike then the triangular relations between the points can be inferred. The stimuli 1 & 2 are more similar than 2 & 6 which are more similar than 1 & 6.

For 6 stimuli there are 20 such triads.

These triangular relationships can be transformed into a single rank order by Coombs' method of Triangular Analysis.

Our subjects were 20 kindergarten and 20 third grade children. The mean ages were 6.0 and 9.1 years respectively. These children were Chinese-American, but we have also tested a white population, and we will note the differences.

The stimuli are diagrammed in Figure 2. Set 1 varied only in hue. 4 inch circles were constructed of Munsell papers of the notation indicated. Set 2 varied only in size. The squares ranged from 1½ inches to 4 inches differing by ½" steps. Set 3 varied only in shape. The shapes consisted of five regular polygons of 3, 4, 5, 7, and 12 sides and a 3 in. circle. The polygons could each be inscribed in a 3 in. circle. The triadic judgments for each child on each set were analyzed in separate triangular matrices. There were one hundred and twenty in all - Forty children times 3 sets.

If the child's judgments were completely systematic, the judgments could be resolved into a single rank order with no inconsistencies. In practice, inconsistencies appeared in many rank orders. Pair 1-2 might be seen as more similar than 2-4, 2-4 more similar than 2-5, 2-5 more similar than 2-6, but 2-6 more similar than 1-2. This produces an inconsistency. One of these relationships must be ignored if a rank order is to emerge. We arbitrarily chose to break these circular relationships by finding the order with the fewest inconsistencies.

We counted these inconsitencies for all our subjects. The mean numbers are given in Table 1. We also analyzed 50 randomly generated protocals to be able to evaluate the performance of our subjects against

chance values. Even our least consistent group - the kindergarten children on the color set - was much better than chance. Thus the kindergarten children were fairly consistent on all the sets. However, the third grade children were even more consistent. There were significant differences between the groups on color and shape. Since the average number of inconsistencies on the shape set is about 1.3 for college students, the 3 rd graders have room for improvement but not a great deal.

Our next analysis focused on the type of inconsistencies. We define 2 types. Type 1 or nested errors occur when the subject judges for example 6 to be more like 1 than 4 assuming a 1, 2, 3, 4, 5, 6 order. It is an error which indicates the subject doesn't have a clear idea of the order of the stimuli.

Type 2 or unnested errors occur when the subject is inconsistent about internal relations - is 4 more like 1 or 6. If he thinks 4 and 1 are most similar but on a subsequent trial with 1, 3, and 6 considers 3 more like 6, there is an inconsistency, but it seems much less serious than the type 1 error.

The percentage of expected Type 1 errors is 67% in random protocols, but the percentage will be 0% if the 1 to 6 general order is maintained. Type II errors will disappear only if the metric relationships between the stimuli are coded and remembered. The results of this analyses are given in Table 2 . All percentages are significantly less than chance except for the kindergarten children on the color stimuli. It would seem that the color stimuli are less adequately ordered by the younger children, but that they become more ordered by the 3rd grade.

Up to this point we have not constrained the rank orders to any pre-conception of the experimenters. Our next analyses deviated from this

procedure. We wanted to know whether the children ordered the stimuli as in Figure 2. Such a basis for response would produce a rank order similar to that indicated in the middle of page 2. The order given is just a sample: the first five pairs could be in any order among themselves, as can be the next four, the next three and so forth. Unsatisfied relationships were scored if the rank orders deviated from this class of rank orders. If for example 16 and 26 were reversed, there would be an unsatisfied relationship since 26 ought to be more similar than 16. If 1-6 was considered the most similar pair and was placed in the first position with the order otherwise maintained there would be 8 unsatisfied relationships and so forth. This is simply a measure of conformity to our conception of the stimuli. Again the kindergarten children seemed unusual and the difference between the number of unsatisfied relationships for kindergarten and third grade children was significant.

Finally we come to the scaling results. Once again the rank orders were not constrained by the experimenters. We determined whether each rank order fit into a single dimension. We used the PARSCAL program referenced on the handout. The index of good fit, θ, was calculated from the 50 random cases. Any solution better than 95% of the random solution was considered a good fit. One hundred out of 120 rank orders met this criterion. The lowest number of good fitting solutions was on the color set for the kindergarten children. 84 of these 100 solutions followed the 1-6 sequence exactly. The other 16 deviated only slightly - usually orders such as 1, 2, 3, 4, 6, 5 instead of 1, 2, 3, 4, 5, 6. Thus we have clear indications that 6 and 9 year old children handle dimensions relationally and in a manner that fits our adult intuitions. However, this relational responding is not so well developed

on the color dimension. Purple is not seen as lying between red and blue in the same way that a 3 inch square lies between a 2 and 4 inch square. By the third grade there is no difference between color and size: color has become dimensionalized to the same degree. There is also an indication of a developmental trend. Eleven out of 20 kindergarten children dimensionalized both color and size. Two children dimensionalized neither. The remaining seven children dimensionalized on size but not on color. No child dimensionalized on color without also dimensionalizing on size. Are these findings reliable? Seventeen individuals from the same population were tested on the color set at the same time, but they, for various reasons, did not do all the tasks. These results are comparable to the kindergarten children as can be seen in Table 5. 40 white kindergarten children also did all three tasks. These results, listed in Table 6, indicate the same sequence of difficulty although they are, in actuality, less consistent and less sophisticated than the Chinese children. The developmental sequence of dimensionalization on size before color was also maintained. Thirteen children dimensionalized on color and size; 13 children dimensionalized on neither; 14 children dimensionalized on size but not color; but there was no color dimensionalization in the absence of size dimensionalization.

In summary, there is an indication that all dimensions are not created equal and should not be used interchangeably in learning problems of the reversal, non-reversal intra-dimensional and extra-dimensional shift type. A child might shift within some dimensions more easily than others because the stimuli in one dimension bear similarity relationships with each other as well as being members of a category. On such a dimension there would be two possibilities for generalization as opposed to only one. Thus size might be

likely to produce more optional ID shifts than color if these dimensions were used. Kendler, Kendler, and Ward found just such a result with shape and color. They found that for preschool and kindergarten children, optional extradimensional shifts were almost as likely as intradimensional shifts on color stimuli, but that, with shape as the relevant dimension, optional intradimensional shifts were five times as likely to be observed as extradimensional shifts.

Pre-existing processing capacities that the child utilizes in learning tasks need not be ignored.

We believe we have also developed an alternate technique for studying seriation and transitivity in children since our procedure offers several measures of the quality of one dimensional seriation.

References

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uestions: 1) Do children process dimensions in the sense of ordered continua?
2) Is this an age related phenomenon?
3) Are there dimension specific effects?

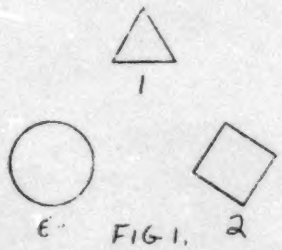

FIG 1.

ie task: Which two are most alike in Fig. 1?
Which two are least similar?
All possible triads are presented in a random order

If 1 is judged most like 2, and
1 is judged least like 6,
then land 2 are more similar than 2 and 6 which are more similar than 1 and 6

These triangular relationships are transformed by Coombs' method of triangular analysis (Coombs, A Theory of Data)*

The three sets of stimuli used in the study are diagramed in Fig. 2

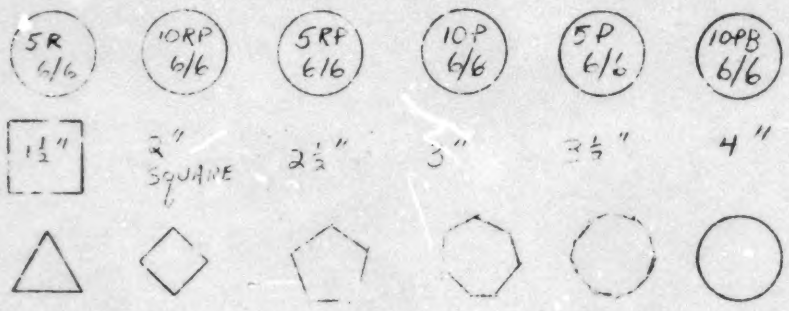

FIG 2

If the child answered completely systematically the judgments could be resolved into a rank order with no inconsistencies. Chance or random responding would produce rank orders with many inconsistencies.

Table 1
Mean number of Inconsistencies

	Kindergarten	3 rd grade	
Color	3.35	1.20	$p < .05$ U=106
Size	2.90	2.60	
Shape	2.95	1.90	$p < .05$ U= 120
Random Input	9.62	(significantly greater than k color, t 7.74 $p < .001$	

Are the subjects consistent? Yes
Are there age differences ? Yes

* a computerized version is available from the first author. UMBC, 5401 Wilkens, Baltimore, Md. 21228. A Program abstract will appear in Behavior Research Methods and Instrumentation, July, 1975.

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What kind of inconsistencies occur?

Type 1: Is 6 more like 1 or 4 = nested error possible

Type 2: Is 4 more like 1 or 6 = unnested error possible

Type 1 errors should be infrequent if the child orders the stimuli:

1 2 3 4 5 6

but more frequent if there is no order. Chance expectancy of type 1 errors is 67% but will be zero if the 1 to 6 order is held.

Table 2
Frequency of Nested (Type 1) errors

	Kindergarten	3 rd grade
Color	.62	.35
Size	.34	.16
Shape	.36	.26

Does each rank order conform to the following order:

Most Similar to Least Similar

12 23 34 45 56 13 24 35 46 14 25 36 15 26 16 ?

Table 3
Mean number of unsatisfied relationships
(The median is in parentheses)

	Kindergarten	3 rd grade	
Color	4.65 (3.0)	1.70 (1.5)	U= 88, p .002
Size	2.00 (1.0)	1.30 (0.0)	
Shape	3.95 (1.0)	2.15 (1.0)	

Do the rank orders fit into a single dimension?**

100/120 rank orders fit into one dimension i.e. 100 out of 120 rank orders had an index of good fit lower than all but 5% of random inputs

Table 4
The number of acceptable one dimensional solutions

	Kindergarten	3 rd grade
Color	11/20	19/20
Size	18/20	19/20
Shape	15/20	18/20

**Analyzed by the PARSCAL program (Johnson, 1973 in Psychometrica, 38, 11-18.)

Major Findings:

The color dimension is different from the other dimensions:

More inconsistencies

High percentage of nested inconsistencies

More unsatisfied relationships

Fewest one dimensional solutions

The color dimension resemble the other dimensions, but not until the third grade.

Is this finding reliable?

Table 5
Performance of 17 additional subjects on the color stimuli

Inconsistencies	3.1 (vs 3.35)
% nested errors	59 (vs 62)
Unsatisfied relationships	4.6 (vs 4.65)
One dimensional PARSCALS	10/17 (vs 11/20)

Table 6
Performance of 40 kindergarten white children , all measures

	Inconsistencies	% nested	Unsatisfied relations	1 D PARSCALS
Color	4.9	69	8.5	13/40
Size	3.35	41	3.95	27/40
Shape	4.6	55	6.75	19/40